A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

1

LA-UR -88-1103

CONF-881015--7

LA-UR--88-1103

DE88 009148

TITLE: CONFINEMENT DYNAMICS IN THE REVERSED FIELD PINCH

AUTHOR(S): K. F. Schoenberg
The ZT-40M Team

SUBMITTED TO IAEA, 12th International Conference on Plasma Physics and Controlled Nuclear Fusion Research
Nice, France
October 12-19, 1988

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

MASTER

FORM NO 836 R4
ST NO 2629 5/81

CONFINEMENT DYNAMICS IN THE REVERSED FIELD PINCH

The ZT-40M Team
Los Alamos National Laboratory

Los Alamos, New Mexico, 87545 USA

The study of basic transport and confinement dynamics is central to the development of the reversed field pinch (RFP) as a confinement concept. Thus, the goal of RFP research is to understand the connection between processes that sustain the RFP configuration and related transport/confinement properties. Recently, new insights into confinement have emerged from a detailed investigation of RFP electron and ion physics. These insights derive from the recognition that both magnetohydrodynamic (MHD) and electron kinetic effects play an important and strongly coupled role in RFP sustainment and confinement dynamics. In this paper, we summarize the results of these studies on the ZT-40M experiment.

ION DYNAMICS

The rapid (compared to electron-ion equipartition) heating of ions to levels where $T_i \simeq T_e$ is a common feature of the ohmically driven RFP.[1,2] In addition, under certain operating conditions, ion temperature has been observed to exceed electron temperature by factors of 3 to 4.[3] These observations suggest that the ions are strongly heated by non-classical processes.

Within the context of MHD, the quantity $(1 - \eta_k/\eta_w)$, where η_k and η_w are the global resistivity determined from magnetic helicity and energy balance respectively, indicates the fraction of total input power (VI) absorbed by fluctuations in the discharge.[4] On ZT-40M, this quantity is a strong function of the pinch parameter Θ ($\Theta = B_\phi(a)/\langle B_\phi \rangle$) and independently, of the rate of current rise (ramping) in the discharge. For example, under standard, "flat-topped" operating conditions, where $\Theta \simeq 1.4$ and $T_i \sim T_e$, $(1 - \eta_k/\eta_w) \sim 0.25$. However, for conditions exhibiting strong ion heating, where $T_i \sim 4T_e$, $\Theta \sim 1.7 - 1.8$ and the current ramping rate is 14-19 MA/sec, $(1 - \eta_k/\eta_w) \sim 0.4 - 0.5$.[5]

The strong experimental correlation of $(1 - \eta_k/\eta_w)$ with ion temperature is indicative of fluctuation-driven ion heating. Furthermore, strong ion heating is seen to experimentally correlate with discharges that exhibit high levels of dynamo activity. This dynamo or fluctuation activity can be driven by a combination of MHD and electron kinetic effects, and can affect both the ion and electron dynamics.

ELECTRON DYNAMICS

Energetic electrons, with long collisional mean free paths, have consistently played a significant role in the dynamics of the RFP edge plasma. Their effect is essentially manifest as a large (factors of 4 to 5) power flux asymmetry along the local magnetic field that intercepts the wall and limiters. In addition to substantially affecting wall protection and impurity control, energetic electrons can have a direct effect on global RFP confinement.

One useful model[6] of energetic electron dynamics in the RFP modifies the kinetic dynamo theory of Jacobson and Moses[7] to include direct electron momentum loss to the plasma edge. In this model, electrons are accelerated by the applied electric field in the core region of the discharge where the component of **E** along **B** (**E**·**B**) is maximized. A low level of magnetic field stochasticity, driven for example by radial magnetic field fluctuations, allows the momentum of the energetic electrons to transport across the mean magnetic surfaces to the plasma edge region, where momentum is lost by collisional processes and direct wall/limiter impact.

The loss of electron momentum at the plasma edge directly increases the discharge loop voltage and decreases the global energy confinement.[6] The magnitude of the momentum loss is dependent on the level of magnetic field stochasticity (or field diffusivity), the electron-ion collisional mean-free path (λ_o), and the ratio of the applied electric field (E_ϕ) to critical field ($E_c = kT_e/(2e\lambda_o)$) in the discharge. In presently operating RFP experiments, such as ZT-40M, the "non-classical" contribution to global resistivity by electron momentum loss may be as high as 50%. This contribution is expected to drop in the next generation of RFP experiments (ZTH, RFX) due to operation with reduced field diffusivity and at lower values of E_ϕ/E_c.

The concept of electron momentum diffusion provides a natural link to the MHD dominated ion dynamics described above. If energetic electrons carry a substantial fraction of the mean current in the edge plasma region, as preliminary measurements on ZT-40M suggest,[8] then their generation and transport physics can directly effect the mean field profiles and MHD stability of the discharge. On the other hand, the magnetic field diffusivity that drives the electron momentum transport is directly related to MHD fluctuational activity. Thus, there exists a natural connection between MHD and kinetic process, and their associated effects on the electron and ion dynamics. This conceptual model of confinement provides guidance for continuing research in the areas of RFP confinement, transport and sustainment physics.

This work supported by the U. S. DOE

[1] R. B. Howell and Y. Nagayama, Physics of Fluids **28**, 743 (1985).

[2] K. Ogawa, Y. Maejima, T. Shimada, Y. Hirano, and Y. Yagi, Nuclear Fusion **25**, 1295 (1985).

[3] G. A. Wurden, K. F. Schoenberg, M. M. Pickrell, D. A. Baker, C. J. Buchenauer, L. C. Burkhardt, T. E. Cayton, R. E. Chrien, J. N. Downing, R. F. Ellis, P. F. Gribble, A. Haberstich, R. B. Howell, J. C. Ingraham, G. Miller, J. Melton, R. W. Moses, C. P. Munson, R. A. Nebel, J. A. Phillips, W. Reass, A. E. Schofield, P. G. Weber, and D. M. Weldon, in *International School of Plasma Physics, Course and Workshop on Physics of Mirrors, Reversed Field Pinches and Compact Tori* (Varenna, Italy, 1987).

[4] K. F. Schoenberg, R. W. Moses, Jr., and R. L. Hagenson, Physics of Fluids **27**, 1671 (1984).

[5] G. A. Wurden, P. G. Weber, K. F. Schoenberg, A. E. Schofield, J. A. Phillips, C. P. Munson, G. Miller, J. C. Ingraham, R. B. Howell, J. N. Downing, R. E. Chrien, T. E. Cayton, L. C. Burkhardt, R. J. Bastasz, S. E. Walker, A. M. Preszler, P. G. Carolan, and C. A. Bunting, in *15th European Conference on Controlled Fusion and Plasma Physics*, Vol. , p. (European Physical Society, Dubrovnik (Cavtat), 1988)

[6] R. W. Moses, K. F. Schoenberg, and D. A. Baker, Empirical modeling and the dependence of reversed field pinch loop voltage on edge plasma conditions, LA-UR-87-3067, submitted to Physics of Fluids.

[7] A. R. Jacobson and R. W. Moses, Phys. Rev. A **29**, 3335 (984).

[8] J. C. Ingraham, Bulletin of the American Physical Society **32**, 1785 (1987).